

APPLICATION FOR LETTERS PATENT OF THE UNITED STATES

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METHOD AND APPARATUS TO TUNE ROTOR'S TORSIONAL NATURAL  
FREQUENCY BY GEOMETRY OF ROTOR WINDING SLOT

TO WHOM IT MAY CONCERN, THE FOLLOWING IS A SPECIFICATION  
OF THE AFORESAID INVENTION

**METHOD AND APPARATUS TO TUNE ROTOR'S TORSIONAL NATURAL  
FREQUENCY BY GEOMETRY OF ROTOR WINDING SLOT**

**Field of the Invention**

This invention relates to rotors used in electrical machines, and more particularly, this invention is related to controlling the torsional  
5 natural frequency of a rotor.

**Background of the Invention**

Rotors are used in many different types of electrical machines, including generators, motors and  
10 other similar devices. The rotor in large cylindrical rotor generators is typically made of a single magnetic steel forging. The rotor is cylindrically configured with an outer peripheral surface, having winding slots that are defined by radially projecting winding teeth  
15 positioned on the rotor body. Winding wire is then looped about the winding slots at specific areas to form a winding coil.

The rotor winding slot has a north and south pole and a direct (D) axis aligned with the poles and a  
20 quadrature (Q) axis midway between poles. The rotor has a natural torsional frequency that is affected by several parameters, mainly, its torsional stiffness and added polar mass moment of inertia  $WR^2$ .

For reasons of stress, fatigue, performance  
25 and other similar reasons, it is desirable to have the torsional natural frequency of the rotor avoid certain values or a range of values. There are numerous prior

art methods and systems presently available to control or change the torsional natural frequency of a rotor, especially by the selective choice or changes to any shaft and rotor geometry. Each of these tuning methods and systems, such as the use of geometry choices or changes, typically exhibit a negative effect on another parameter, such as the cost, size, performance, and ability to manufacture the overall machine design.

Other rotor geometries can be designed to suppress undesired pulls and field distortion, production of noise, reduce bearing wear, and increase the power output of a motor. For example, in U.S. Patent No. 2,698,910 to Blyth, an armature has a toothed structure to form an asymmetrical relation to the motor field and provide a means for suppressing the undesired pulls and field distortion production of noise. It also reduces bearing wear. A plurality of small, half-round dummy slots, or grooves, are positioned in the center of each armature tooth.

U.S. Patent No. 4,827,172 to Kobayashi discloses a DC motor rotor core having a plurality of shallow and deep slots that are circumferentially and alternatively disposed in the peripheral face of the rotor core at angular intervals about the center axis. This structure increases the power output of the motor by increasing the number of turns, but does not work for torsional tuning by adjustment and selection in a desirable manner.

### Summary of the Invention

The present invention is advantageous and now provides torsional tuning with less negative impact on the overall machine design than prior art methods. In accordance with one aspect of the present invention, a method for tuning the torsional natural frequency of a

rotor is disclosed and comprises the step of forming within winding slots defined by radially projecting winding teeth at least one tuning slot that extends radially inward from the bottom of the winding slot a distance to tune the rotor to a desired torsional natural frequency. This tuning slot can have a width smaller than the width of any winding wire received within the winding slot to prevent winding wire from passing into the tuning slot. The tuning slot can be positioned at a location that minimizes impact to the electromagnetic characteristics of the rotor cross-section, such as in slots in proximity of the Q-axis. At least one tuning slot that extends radially inward from the bottom of the winding slot is positioned at the quadrature axis.

In yet another aspect of the present invention, a rotor includes a rotor shaft and a cylindrically configured rotor body having a plurality of radially projecting winding teeth that define winding slots for receiving winding wire therein. The winding slots have a bottom that is spaced radially inward. At least one tuning slot extends radially inward from the bottom of the winding slot a distance that tunes the rotor to a desired torsional natural frequency.

#### **Brief Description of the Drawings**

Other objects, features and advantages of the present invention will become apparent from the detailed description of the invention which follows, when considered in light of the accompanying drawings in which:

FIG. 1 is an isometric view of a rotor of the present invention showing winding slots defined by winding teeth and at least one tuning slot.

FIG. 2 is a sectional view taken along line 2-2 of FIG. 1.

FIG. 3 is an enlarged view of the winding slots positioned at the quadrature axis, and showing the tuning slots located in some of the winding slots.

### Detailed Description of the Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

FIG. 1 illustrates generally at **10** a perspective view of a rotor, in accordance with the present invention, and shows a stepped shaft **12** of the rotor with a turned down smaller diameter end **14**, and a larger diameter stub portion **16**. The rotor body **20** is formed as a single piece forging with the shaft.

The rotor body **20** is cylindrically configured as known to those skilled in the art and is formed as a solid, single piece. It includes a plurality of winding slots **30** that are defined by a plurality of radially projecting winding teeth **32**. The winding slots **30** are deep enough to allow sufficient winding wire to be looped about the winding slots and form the rotor coils, as known to those skilled in the art. As shown in the sectional view of FIG. 2, the D-axis

corresponds to north and south poles and in some embodiments, includes a quadrature (Q) axis.

In accordance with the present invention, at least one tuning slot **34**, and preferably, a plurality of tuning slots, extend radially inward from the bottom of predetermined winding slots a distance sufficient to tune the rotor to a desired torsional natural frequency. FIGS. 2 and 3 illustrate the tuning slots **34** positioned at the bottom of the winding slots **30**. The tuning slots are typically dimensioned smaller than the width of any winding wire received within the winding slot and prevent winding wire from passing into the tuning slot. In some instances, however, the tuning slots could be dimensioned wide enough to receive the winding wire, but this technique would not be preferred.

The tuning slots **34** are preferably positioned at a location that minimizes impact to the electromagnetic characteristics of the rotor cross-section, and typically at the quadrature axis as shown in FIG. 2. If the tuning slots **34** were positioned closer to the poles, then the tuning slots could interfere with the electromagnetic characteristics of the rotor.

The tuning slots can be formed by a cutter having a larger first width for the winding slots, and followed by an end portion having a smaller width at its edge. This tool would be shaped in a stepped configuration with a more narrow portion extending from the wider part to form the tuning slot. In most instances, however, it is expected that one skilled in the art would select a first cutter for forming the winding slots, and then replace that first cutter with a second cutter for entry into the winding slots to form the tuning slots. The term cutter wheel is a

general term, and could refer to the grinding wheels on high speed cutters used by those skilled in the art.

It is possible also to use software programming with algorithms known to those skilled in the art for determining the depth, number and location of the tuning notches. The present invention is advantageous and provides tuning notches that reduce the torsional stiffness and increase the added polar mass movement of inertia of a rotor shaft and rotor body with the cross-section of the rotor body. It is relatively easy to manufacture the tuning notches as a one or two step process and the depth, number and location of the tuning notches can be determined by appropriate software algorithms, as known to those skilled in the art.

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed, and that the modifications and embodiments are intended to be included within the scope of the dependent claims.